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Polychlorinated Biphenyls and the Environment

Interdepartmental Task Force on PCBs
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This report is the product of a six month review of the chemicals known as PCBs--polychlorinated biphenyls--by five Federal agencies, with participation by other agencies. The Interdepartmental Task Force on PCBs had as its goal the coordination of the scientific efforts of the Government aimed at understanding PCBs and the strengthening of the Government's ability to protect the public from actual or potential hazards associated with them. The task force made nine findings, conclusions, and recommendations, primarily pointing out that PCBs should be restricted to essential or nonreplaceable uses which would minimize the likelihood of human exposure or leakage to the environment. Supplementing the 20-page report are eight appendices detailing current knowledge about various aspects of PCBs, including their use and replaceability; occurrence, transfer, and cycling in the environment; occurrence and sources in food; and PCBs effects on man and animals.

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PREFACE

On September 1, 1971, representatives of several agencies of the Federal Government established an interdepartmental task force to coordinate the scientific efforts of the Government aimed at understanding the family of chemical compounds known as polychlorinated biphenyls (PCBs), and to strengthen the Government's ability to protect the public from actual or potential hazards from PCBs. On September 5 it was announced that the task force would "coordinate a government-wide investigation into PCB contamination of food and other products". On September 13 the task force, made up of qualified specialists from a range of disciplines, held the first of a series of meetings. Appropriate spokesmen on various problems associated with PCBs were assigned to prepare a series of background papers, drawing on the resources of their own and other agencies.

The task force included operating units of five Executive Branch departments: Department of Agriculture; Department of Commerce (Assistant Secretary for Science and Technology and National Oceanic and Atmospheric Administration); Environmental Protection Agency; Department of Health, Education, and Welfare (Food and Drug Administration and National Institute of Environmental Health Sciences of the National Institutes of Health); and Department of the Interior (Bureau of Sport Fisheries and Wildlife).

The report which follows represents the results of the task force's review and reflects the position of the operating agencies of the Federal Government which have major responsibilities concerning such chemicals as PCBs in food and in the environment. The task force had the advantage of some additional sources of information and review on PCBs. For example, during the course of the study, the National Institute of Environmental Health Sciences sponsored an international scientific meeting on PCBs on December 20-21, 1971, at the Quail Roost Conference Center, Rougemont, North Carolina. One hundred persons--from Government, universities, industry, and the press--attended. The proceedings of this conference soon will be published by the Institute. The task force also met from time to time with a group of scientific advisors from outside the Federal Government, which was already at work prior to September 1971 examining a number of hazardous trace substances, one of which was PCBs.

The individuals who served on the task force included: Dr. John E. Spaulding and Dr. Harry W. Hays (Department of Agriculture), Dr. Robert W. Cairns and Dr. William Aron (Department of Commerce), Dr. John Buckley (Environmental Protection Agency), Dr. Lawrence Fishbein, John R. Wessel, and Dr. Albert Kolbye (Department of Health, Education, and Welfare), Dr. Lucille Stickel (Department of the Interior), Dr. Edward J. Burger, Jr. (Office of Science and Technology), and Dr. Terry Davies (Council on Environmental Quality). Many others participated in some of the meetings and lent assistance in a variety of ways including authorship of background papers published as appendices in this report. The task force is grateful for this assistance.

The task force will continue to assess new information that comes to its attention.

FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

Polychlorinated biphenyls (PCBs) have been used in the United States and elsewhere over the past 40 years, for many industrial and consumer applications. During the past three years evidence has accumulated to indicate that PCBs are widely dispersed throughout the environment and that they can have adverse ecological and toxicological effects.

The principal uses for PCB fluids are in the electrical industry. PCBs have superior cooling, insulating, and dielectric properties and hence are widely used in various electrical devices. Transformers and capacitors filled with PCBs can be used in inside locations where failures of oil-insulated equipment would present a potential danger to life and property. Because PCBs are relatively nonflammable, apparatus containing them is essentially free from the fire and explosion hazards associated with oil-insulated and oil-cooled electric devices. Stability at high temperatures is another major factor in the attractiveness of these compounds. The principal advantage of PCBs over substitutes is the relative freedom from flammability in some applications that previously had been plagued by serious fires. PCBs also give electrical equipment the critical advantages of reliability, long life, and compactness. PCB impregnated capacitors, for example, are markedly more reliable and long-lived, and 1/6 the size, 1/5 the weight, and 1/4 the cost of comparable oil impregnated capacitors. Small capacitors with PCBs have a use-life expectancy of 10 to 15 years, and large capacitors 20 to 25 years. PCBs in transformers are replaced only every 25 to 30 years.

PCBs have been discovered to have a widespread distribution in the environment, and some environmental occurrences have been associated with adverse effects on certain forms of animal life. Beginning in 1971, the Monsanto Company, the sole U. S. producer, has reported taking voluntary actions to reduce the volume of PCB production and to limit its distribution to industries concerned with the manufacture of electrical apparatus. Similar restrictions have been put into effect by statute in Sweden and voluntarily in Great Britain.

A large use of PCBs had been in carbonless duplicating paper. This use has been discontinued. The Food and Drug Administration and the food industry have increased their surveillance to assure that PCBs are not used in food plants, products, or packaging.

The task force has reviewed all of the available scientific information on various aspects of the PCB problem. It has found much data that it regards as inadequate and many questions that remain unanswered. But on the basis of available information, the task force concurs on the following findings, conclusions, and recommendations:

1. PCBs should be restricted to essential or non-replaceable uses which involve minimal direct human exposure since they can have adverse effects on human health. There currently are no toxicological or ecological data available to indicate that the levels of PCBs currently known to be in the environment constitute a threat to human health, but additional experiments are underway to evaluate the impact of low level, long-term exposure to PCBs.

2. PCBs have been used so widely over such a long period that they are ubiquitous. Even a total cessation of manufacturing and use of PCBs would not result in the rapid disappearance of the material, and ultimate disappearance from the environment will take many years. The elimination of non-essential uses and prohibition of discharges from essential uses will result in gradual elimination from the environment.

3. PCBs were first identified as potential food contaminants in 1966. Three principal sources or routes of contamination of food have been identified. General environmental contamination has resulted in PCB residues in some fresh water fish. Prohibition of PCB discharges into water will result in the reduction of such residues. Another route occurs from the presence in food packaging materials of PCB residues, some of which migrate into packaged food. The FDA has proposed regulations for food packaging materials and foods to deal with this problem. The third route involves accidental contamination of food from leakage or spillage of PCBs into feed or directly into food. The dietary intake of PCBs is of low order and does not present an imminent health hazard. To date, all of the high levels of PCBs encountered in human or animal foods have been associated with accidents, for which Government agencies have exercised necessary regulation and control to minimize the distribution of contaminated foods.

4. The sole domestic producer of PCBs, Government agencies, and key user industries are taking appropriate steps to cut off further introduction of PCBs into the food supply and to reduce the current levels of PCBs as food and environmental contaminants. The Food and Drug Administration (FDA) has acted, under the authority of the Food, Drug, and Cosmetic Act, to preclude the accidental PCB contamination of food. It has also proposed a prohibition on the use in food packaging materials of pulp from reclaimed and salvaged fibers that contain poisonous or deleterious substances that may migrate into the food if the contamination by such substances is deliberate or avoidable. It has proposed temporary tolerances for unavoidable PCB residues in food packaging materials and in certain foods. The Department of Agriculture has acted under the Wholesome Poultry Act and other statutes to prevent accidentally contaminated foods from reaching the market.

The major gap in the regulatory system to deal with PCBs is the absence of any broad Federal authority to restrict use or distribution of the chemical, to control imports, and to collect certain types of information. The task force believes that such authority is needed. This authority would be provided by the Toxic Substances Control Act proposed by the Administration and now pending before Congress.

5. Housekeeping is particularly important in the manufacture, use, and disposal of PCBs. Under a program of limitation on the sale of PCBs, the electrical industry will continue to be the principal user of PCBs; it, as well as industries now holding inventories of PCBs, have a special responsibility for monitoring and controlling their wastes. In this connection, the Environmental Protection Agency will restrict industrial liquid discharges of PCBs from PCB users. To keep levels in fish as low as possible, and in any case below FDA's interim action level of 5 parts per million, concentrations in rivers or lakes from all sources should not exceed 0.01 parts per billion.

6. The use of PCBs should not be banned entirely. Their continued use for transformers and capacitors in the near future is considered necessary because of the significantly increased risk of fire and explosion and the disruption of electrical service which would result from a ban on PCB use. Also, continued use of PCBs in transformers and capacitors presents a minimal risk of environmental contamination. The Monsanto Company, the sole domestic producer, has reported voluntarily eliminating its distribution of PCBs to all except manufacturers of electrical transformers and capacitors.

Pending passage of the Toxic Substances Control Act, the Federal Government does not have the legal authority to impose restrictions corresponding to the actions reported by Monsanto. Although some Federal enforcement authority is available, the Federal Government does not have the authority to control PCBs at their source.

7. Most capacitors presumably have been disposed of in landfills. PCB containing material buried in soil is not expected to migrate but should remain in place. In the past, many fluids containing PCBs have been disposed of in sewers. More appropriate means of disposal such as high-temperature (at least 970°C) incineration must be used instead.

8. PCBs are manufactured in countries other than the United States. Importation of PCBs as a chemical or as a component in products remains legally possible because the Toxic Substances Control Act has not yet become law. Electrical products imported from abroad may contain PCBs. The task force looks to international agreements to bring about some multi-national understanding on the sale and use of PCBs globally. Importation of PCBs for uses other than those singled out in the present pattern of voluntary limitations should be avoided by users.

As an additional measure, the United States has asked the Organization for Economic Cooperation and Development (OECD) through its Environment Committee to make a special review of member states' national policies concerning PCBs and also to identify products moving in international trade which contain PCBs. OECD, whose membership includes all major Western industrialized states plus Japan and Australia, has been giving priority attention to the problem of PCBs over the past year.

9. More scientific information about PCBs is needed, and several Government agencies are seeking it through research. The task force recognizes that the scientific basis of much of our knowledge must be

strengthened through research. The total exposure of a human being to a given substance from all sources--air, water, and food--must be considered, and interactions of PCBs and other substances within and outside the body must be evaluated. Similar consideration must be given to the other body organisms.

Current scientific knowledge gained from laboratory animal experiments is often inadequate to allow reliable interpretation of the data in terms of possible effects on man. The scientific basis for interpreting such tests must be improved.

The situation regarding PCBs is not significantly different from the problem of other toxic susbstances which cause concern when they come into contact with man, his food, and his environment. Continuing vigilance on the part of Government agencies, industry, universities, and many other agencies both within and outside the Government will be necessary to achieve an effective system for assessing and controlling the hazards of toxic substances, including PCBs.

The task force, by reviewing research needs and the present Federal research effort, has helped to insure that these efforts of the agencies are well planned and coordinated. Certain Government laboratories as well as a number of non-Government scientists recently have embarked on additional research on PCBs, and the results will be communicated to the scientific public completely and promptly through normal channels such as meetings and journals.

I. PRODUCTION, DISTRIBUTION, AND USE OF PCBS

Polychlorinated biphenyls (PCBs) were first manufactured commercially in 1929. By virtue of their unusual chemical and physical properties, they achieved widespread use in a variety of applications. PCBs are now manufactured in Great Britain, France, Germany, the USSR, Japan, Spain, Italy, and Czechoslovakia, as well as in the United States.

In the United States, PCBs have been manufactured by a single producer, the Monsanto Company, and marketed under the tradename "Aroclor". Table 1 gives a breakdown, by category of use and by type of PCB, of the total U. S. production, domestic sales, and U. S. export sales from 1957 to the present. Figure 1 and Figure 2 summarize these data for the years 1963 through 1971.

Both production and domestic sales of PCBs roughly doubled between 1960 and 1970. If one assumes a constant rate of growth of domestic sales since 1930, the cumulative sales in North America by 1970 would be of the order of 500,000 tons. (1) Corresponding data on production and use of PCBs outside the United States are not available. Current estimates suggest that total U. S. production represents roughly one-half of the total world production.

As can be seen in Table 1, the majority of the PCB material produced in the U. S. was marketed domestically. Between 1963 and 1971, the proportion of the production which was exported averaged 13 percent. In 1971, the Monsanto Company reportedly undertook a variety of voluntary restrictions on the distribution of PCBs to various categories of industries. Both

TABLE 1
PCB MANUFACTURING AND SALES
DATA FROM MONSANTO INDUSTRIAL CHEMICALS CO.
1957 THROUGH 1971
(Thousands of Pounds)

	1957	1958	1959	1960	1961	1962
TOTAL PRODUCTION (For Domestic Sales)(1)				37919	36515	38353
DOMESTIC SALES	32299	26061	31310	35214	37538	38043
DOMESTIC SALES BY CATEGORY						
Heat Transfer	-	-	-	-	-	157
Hydraulics/Lubricants	1612	1549	2685	2523	4110	3915
Misc. Industrial	704	755	1569	1559	2114	1681
Transformer	12955	5719	5984	7921	6281	7984
Capacitor	17028	14099	16499	16967	15935	15382
Plasticizer Applications(2)		3939	4573	6244	9098	8924
Petroleum Additives	-	-	-	-	-	-
Total	32299	26061	31310	35214	37538	38043
DOMESTIC SALES BY PCB GRADE						
Aroclor 1221	23	16	254	103	94	140
Aroclor 1232	196	113	240	155	241	224
Aroclor 1242	18222	10444	13598	18196	19827	20654
Aroclor 1248	1779	2559	3384	2827	4023	3463
Aroclor 1254	4461	6691	6754	6088	6294	6325
Aroclor 1260	7587	5982	6619	7330	6540	6595
Aroclor 1262	31	184	359	326	361	432
Arcolor 1268	-	72	102	189	158	210
Total	32299	26061	31310	35214	37538	38043

NOTE: (1) Production amounts prior to 1960 are not available.
(2) Amounts for plasticizer applications prior to 1958 are not available.

TABLE 1 (cont.)

	1963	1964	1965	1966	1967	1968	1969	1970	1971	Prospect 1972
U.S. PRODUCTION	44734	50833	60480	65849	75309	82854	76387	85054	40471	25-30 m
DOMESTIC SALES (LBS.)	38132	44869	51796	59078	62466	65116	67194	73061	37635	25-30 m
U.S. EXPORT SALES	3647	4096	4234	6852	8124	11231	10624	13651	9876	?
U.S. DOMESTIC SALES BY CATEGORY										
Heat Transfer	582	929	1237	1766	2262	2529	3050	3958	3480	-
Hydraulics/Lubricants	3945	4374	4616	4258	4643	5765	8039	7403	1643	-
Misc. Industrial	1528	1692	1841	1779	1426	1283	1079	1627	578	-
Transformer	7290	7997	8657	8910	11071	11585	12105	13828	11528	25-30 m
Capacitor	15606	19540	23749	28884	29703	29550	25022	26708	17305	25-30 m
Plasticizer Applications	9181	10337	11696	13481	13361	14404	16460	19537	3102	-
Petroleum Additives	-	-	-	-	-	-	1439	-	-	-
U.S. DOMESTIC SALES BY PCB GRADE										
Aroclor 1221	361	596	369	528	442	136	507	1476	1600	300
Aroclor 1232	13	13	7	16	25	90	273	260	211	300
Aroclor 1242	18510	23571	31533	39557	43055	44853	45401	48588	21000	4000
Aroclor 1248	5013	5238	5565	5015	4704	4894	5650	4073	261	-
Aroclor 1254	5911	6280	7737	7035	6696	8891	9822	12421	5800	6000
Aroclor 1260	7626	8535	5831	5875	6417	5252	4439	4890	1750	600
Aroclor 1262	414	446	558	768	840	720	712	1023	-	-
Aroclor 1268	284	190	196	284	287	280	300	330	-	-

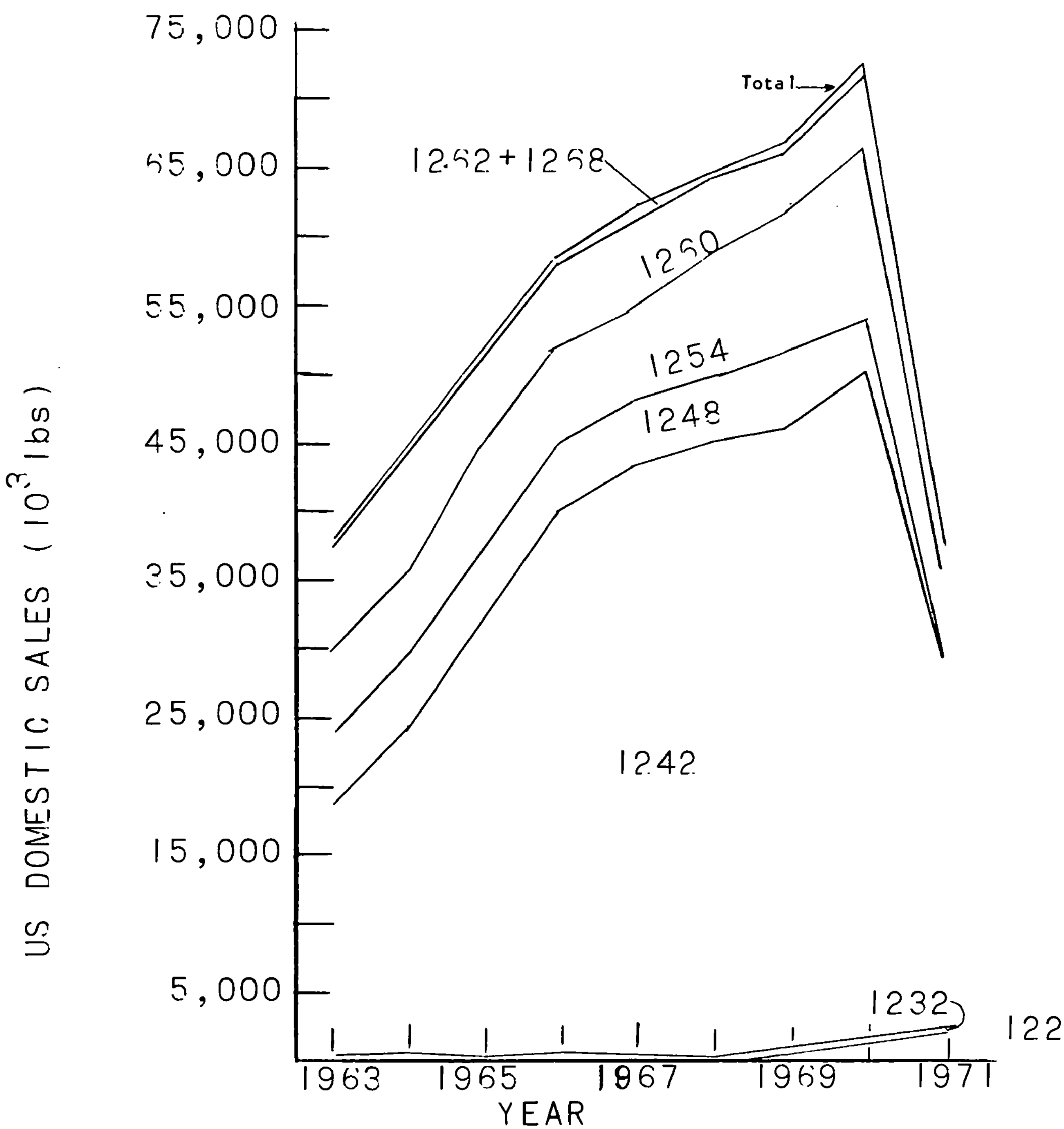

FIGURE 1. US DOMESTIC SALES OF PCBs BY GRADE The uppermost curve represents the total sale

From Nisbet, I.C.T., and Sarofim, A.F. (1)

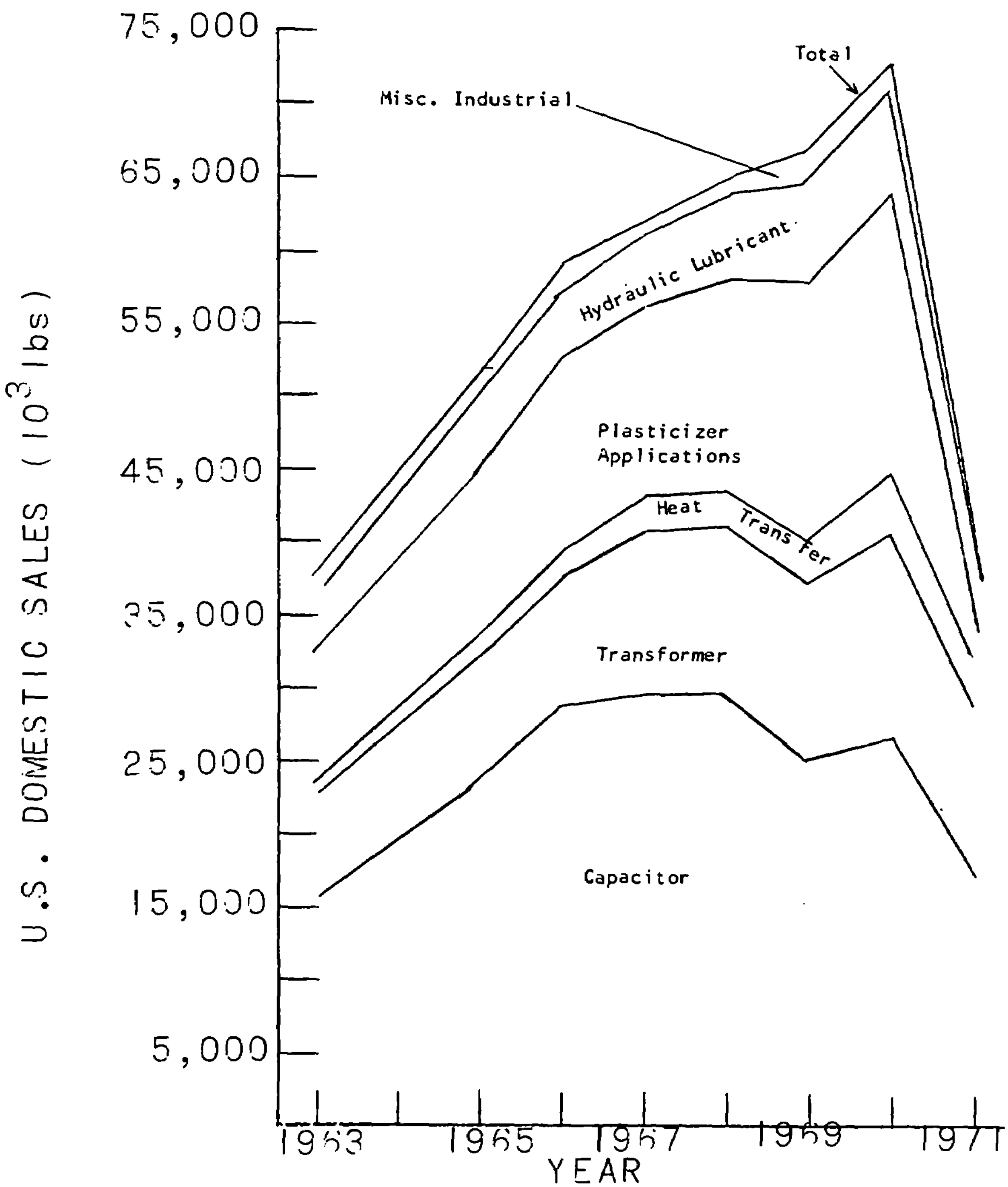

FIGURE 2. US DOMESTIC SALES OF PCBs by Category (The uppermost curve represents the total sales.)

From Nisbet, I.C.T., and Sarofim, A.F. (1)

production and sales figures for 1971 were roughly half of those for 1970, when these volumes were at their peak (Table 1 and Figures 1 and 2). Projections for 1972 indicate an even lower volume.

Prior to 1971, about 40 percent of the PCB material in the United States was used in applications where containment was difficult and losses into the environment were probable. These uses included plasticizers, hydraulic fluids and lubricants, surface coatings, inks, adhesives, pesticide extenders, and microencapsulation of dyes for carbonless duplicating paper. The remaining 60 percent of domestic sales was used mainly in electrical applications (transformers and capacitors). In 1971, this fraction is expected to have reached approximately 90 percent of the total use, only about half of the total use in 1970.

In terms of the grade or family of PCB manufactured, the lower chlorinated species have generally made up the majority of the products produced. From the figures in Table 1 it can be seen that Aroclor 1242 and grades with lower percentages of chlorination characteristically composed one half or more of the total production between 1963 and 1970.

The largest categories of use of PCBs have been in capacitors and transformers and in certain "plasticizer" applications including carbonless duplicating paper. A large percentage of the production of Aroclor 1242 went into these three categories of products. (2) The major uses for PCBs prior to 1970 (in the order of importance as a reflection of the volume of material used) were:

Capacitors
Plasticizer applications
Transformer fluids
Hydraulic fluids and lubricants
Heat transfer fluids

II. CHEMICAL AND PHYSICAL PROPERTIES AND IMPURITIES

Chemical and Physical Properties of PCBs

Theoretically, there are 210 possible PCB compounds, but only about 100 are likely to occur in commercial products. The degree of chlorination determines the chemical and physical properties of the Aroclors; the first two digits of the numbered Aroclor represent the molecular type, the last two digits the average weight percent of chlorine. Their physical state thus varies from colorless, oily liquids to more viscous and increasingly darker liquids to, in the higher series, yellow and then black resins. The PCBs are not readily biodegradable. They resist breakdown by water, acids, and alkalis and have boiling points ranging from 278 to 475°C.

Analytical Techniques

Whereas in the past it was difficult to identify PCBs in the presence of other organochlorine compounds such as DDT and DDE, they can now be separated from interfering compounds and identified and measured by means of thin layer and gas liquid chromatography at levels less than 1 part

per million in food and at significantly lower levels in air and water. Confirmation of their presence and molecular structure is possible by mass spectrometry. Various chromatographic columns and GLC detectors have been most useful in the analyses. Increased precision of residue detection in biological materials has also been made possible through the choice of chlorine specific detectors such as the microcoulometric detectors.

Contaminants and Impurities

The starting materials used in synthesis of PCBs determine to a large degree the type of impurity or contaminant in the commercial product. The contaminant variation, of course, renders some divergence in the LD 50 values or other toxicologic response of the PCBs. Fractionated samples of some PCBs of foreign manufacture have shown them to contain as contaminants the tetra- and pentachlorodibenzofurans, the hexa- and heptachloronaphthalenes. Further work is needed to ascertain whether additional impurities or contaminants are present in the various U. S. and foreign PCB products. Also, variance in biological response to the various PCB products should be correlated with analytical data obtained on the actual or likely presence of contaminants.

III. BENEFITS, UTILITY, AND ESSENTIALITY

The task force reviewed the several categories of uses to which PCBs had been put in the past to determine what was known of their utility and to ascertain if alternate or substitute materials were available or whether any of the present applications were essential.

The four major types of applications examined were:

1. Dielectric fluids for capacitors and transformers.
2. Industrial fluids for hydraulic, gas turbine, and vacuum pump uses.
3. Heat transfer fluids.
4. Plasticizers and miscellaneous uses.

This review of utility was undertaken by the National Bureau of Standards. The review was materially aided by information from the National Industrial Pollution Control Council and from certain professional independent testing and evaluation associations.

A major value of the PCB liquids is that those with four or more substituted chlorines per molecule are nonflammable as are their decomposition products, both vapors and arc-formed gaseous products. Thus they can be used as fluids at temperatures up to 700°F without the danger of explosions and fire. The major disadvantage of the PCBs is their toxicity and environmental contamination. The other comparable class of non-flammable fluids is the fluorocarbons, which typically have a lower vapor pressure and lower boiling point than the chlorinated compounds.

Electrical Uses

PCBs are used in fluids (known as askarels) for electrically insulating and cooling transformers when the transformers are used in or near buildings. Being virtually free of fire and explosion hazards, PCBs can be used where failures of oil-insulated transformers would present a potential danger to life and property. PCBs also are superior to oils in reliability, in making small equipment possible, and in assuring long life and reliability to equipment. Table 1 shows the flammability ratings of two PCBs compared to five other common materials.

Table 1

Underwriters' Laboratories Flammability Ratings

Fluid	Flammability Rating
Ether	100
Gasoline	90-100
Ethyl Alcohol	60-70
Kerosene (100° F.P.)	30-40
Mineral Oil	10-20
Aroclor 1242 and MCS 1016	2-3

PCBs are used in transformers wherever fire protection is particularly important--for about 5 percent of all transformers.

Most of these transformers are located inside public, commercial, or industrial buildings--or on the roof tops of, or in close proximity to, such buildings--and require no special enclosures other than those necessary to prevent accidental hazardous mechanical or electrical contact of persons with the equipment.

The amount of Aroclor used in various types of transformers ranges from 40 to 500 gallons (516 to 6,450 pounds) with an average of about 235 gallons (3,032 pounds). During 1968, the last complete "normal" year for the electrical industry, the total amount of PCBs used in new transformers or as replacement fluid was approximately 1.3 million gallons (8.4 thousand tons).

The only present alternatives to Aroclor-insulated transformers are mineral oil-insulated transformers or dry-type transformers (either those open to the atmosphere or those that are gas-filled and sealed). Mineral oils are the preferred fluids when fire does not create a hazard. Dry transformers also can be used when space is available to install them. Fluorocarbon liquids require a special transformer design.

PCBs are used in more than 90 percent of the electric utility (large power) type and smaller industrial type capacitors made today. They are needed for safety, reliability, and long life, and to achieve sizes compatible with equipment and installation requirements.

Almost 80 million PCB-impregnated capacitors are manufactured annually, most of them for first-time use. The principal types are high voltage power capacitors used primarily for power factor correction in the distribution of electric power; low voltage power capacitors installed in industrial plants at the load (typically large motors); ballast capacitors to improve the efficiency of lighting systems; and small industrial capacitors for power factor improvement in such equipment as air conditioning units, pumps, fans, etc.

Capacitors used in lighting and air conditioning applications contain 0.0005 to 0.09 gallons of PCB per unit. The largest power capacitors contain about 6.7 gallons of askarel. The National Electrical Code requires that any installation of capacitors in which any single unit contains more than 3 gallons of combustible liquid shall be in a vault like that required for transformers. During 1968, the last complete "normal" year for the electrical industry, the amount of PCBs used in capacitors was approximately 14.4 thousand tons.

Possible alternatives to PCB-impregnated capacitors are capacitors impregnated with mineral oil or certain other liquids. Flammable fluids in capacitors used in buildings are not allowed by insurance companies and building codes.

If codes did allow flammable materials in this use, replacement of PCBs in capacitors and transformers would require considerable time and money for re-engineering, manufacture, and application of substitute equipment, and lack of availability of PCBs for this equipment would cause a major and lengthy disruption in the nation's electrical system.

Industrial Applications

PCBs have been useful in hydraulic systems where leakage onto hot metal surfaces could cause fire, but substitute fluids are available. Gas turbines require lubrication at high temperatures. PCBs can be used but tend to be corrosive. Phosphate ester lubricants seem better in this respect. Chemical stability is more important than non-flammability for high temperature lubricants. PCB fluids are useful in diffusion booster pumps, but non-flammability is not especially important for diffusion pump liquids, and alternative liquids are available.

Heat Transfer Materials

Flammable heat transfer fluids present a fire hazard if they leak into a furnace or onto hot surfaces. The use of PCBs prevents this danger. In some cases water is a suitable substitute at moderately high temperatures, and other satisfactory heat transfer fluids are commercially available and in use.

Plasticizers

The PCBs are good plasticizers for use with adhesives, textiles, surface coatings, sealants, and copy paper. In some cases the PCBs act as fire retardants. There are no unique properties of PCBs for plasticizer uses, and equally effective alternatives are generally available (e.g., phosphate esters are often used as fire retardants).

IV. OCCURRENCE, TRANSFER, AND CYCLING IN THE ENVIRONMENT

Given the diversity of uses of PCBs and their chemical characteristics (greater stability in the higher chlorine species), it is not surprising that the residues are widespread. While satisfactory quantitative estimates of the contribution of various pathways into the environment are not possible with existing data, there are enough data to be certain that PCBs do reach the environment at least from the following sources:

-- Open burning or incomplete incineration (at usual temperatures) of solid wastes, municipal and industrial. Incineration at 2000°F or above for two seconds will destroy PCBs, but poorly operated incinerators or open burning may result in PCBs being released to the atmosphere unchanged.

-- Vaporization from paints, coatings, plastics, etc. (Nisbet and Sarofim, 1) estimate that as much as 20 percent may be vaporized.

-- Municipal and some industrial sewers (PCBs present in treated as well as untreated wastes).

-- Accidental spills or improper wastes disposal practices.

-- Formerly, direct application to the environment as ingredients of pesticides or as carriers for pesticides (such uses of PCBs are now prohibited).

-- Dumping of sewage sludge, municipal and industrial solid waste, and dredge spoil at sea.

-- Sewage sludges disposed of on land.

-- Migration from surface coatings (paints, etc.) and packaging materials into foods and feeds.

Probably the largest amounts of PCBs circulating in the environment reach it through industrial and municipal discharges to inland and coastal waters.

The recommendation by the task force that "more scientific information about PCBs is needed" is illustrated by the sparsity of knowledge about PCBs in the environment. Only general statements can be made about how PCBs reach the environment, how they reach target organisms, and how much is present.

Nisbet and Sarofim (1) estimate that the total loss of PCBs into the U. S. environment over the last 40 years would approach 30,000 tons to the atmosphere, 60,000 tons to water and 300,000 tons to dumps. Of this total, remaining residues might be 20,000 tons from the air (which would be distributed on land or water), 30,000 tons in water, and perhaps 250,000 tons in dumps.

Thousands of environmental and biological samples have been analyzed for the presence of PCBs. One or more of the PCB compounds have been detected in all environmental media, and in many organisms.

Water

The water environment is probably the principal sink and transport mechanism for PCBs. Calculations based on measured occurrences in municipal and industrial outfalls, in the receiving waters, and in the downstream reaches of the waterways demonstrate transport through the aquatic system. Measured residues in fishes from various environments suggest accumulations at the downstream ends of the drainageways.

There are few data on removal, disappearance, and sequestering of the substances in soils or bottom sediments of rivers, lakes, estuaries, or the ocean.

Organisms Other Than Man

PCBs being, like many of the organochlorine insecticides, fat soluble, are stored in the lipids of animals. Also like the chlorinated hydrocarbon insecticides, they resist metabolic changes, and tend to be concentrated at succeedingly higher levels in animals higher in the food chain. The higher chlorine PCBs are the most stable.

Occurrence and Sources of PCBs in Food

The identification of PCBs as a potential food contaminant was first reported in 1966. Subsequent investigations, including the development of analytical procedures for PCBs in foods and their incorporation in Federal programs for monitoring the nation's food and feed supply for pesticide residues and other chemical contaminants, established several sources from which foods may become contaminated with PCBs.

Environmental Contamination of Food

PCB residues in fresh water fish appear to be widespread geographically as a result of the environmental contamination of lakes and streams. Depending upon the location of sampling and the species of fish, PCB levels generally range from 1 to 10 parts per million. Foods of animal origin, such as meat, poultry, eggs, and milk contain, in some instances, low background levels of PCBs that may be attributable to environmental contamination.

Industrial Accidents

The widespread industrial uses of PCBs have resulted in a number of identified isolated accidents involving the direct contamination of animal feeds, which, in turn, caused human food to become contaminated.

-- Poultry and eggs became contaminated as a result of the leakage of PCB heat transfer fluid during the pasteurization of fish meal (poultry feed component).

-- PCB residues in milk have resulted from the use of PCB in certain coatings on the inside walls of silos, which, in turn, contaminated the dairy feed silage.

-- The use of spent PCB transformer fluid as a herbicide spray vehicle allegedly contaminated dairy cattle grazing areas thereby causing residues in milk.

-- The grinding of bakery products along with their PCB-containing wrappers for use as poultry feed is suspected to have caused contamination of fowl.

These incidents, as well as others during the past several years, represent localized sources of contamination. Federal, State, and industry actions prevented most of the contaminated foods from being marketed.

Food Packaging

A significant percentage of food paper packaging materials contains PCBs and has resulted in the migration of low levels to the packaged food. This source of food contamination was identified in 1971. The origin of PCBs in packaging materials is not fully understood. Recycled waste paper containing PCB carbonless "carbon" paper. is the prime source of PCB in paperboard product. Virgin paper products, however, have also been shown to contain PCB residues, probably as a result of the paper manufacturing processes. Data on current production of food packaging materials indicate that the levels are decreasing and are controllable so that the potential for PCB contamination of packaged foods can be minimized.

Dietary Intake

National monitoring data, and in particular FDA's total diet studies, indicate that the human dietary intake of PCBs is of a low order. For example: the dietary intake expressed as mg/kg body weight/day, and based on food consumption approximately twice as high as the normal diet, was less than 0.0001 in FY 1971 and 0.0001 in the first-half of FY 1972. As a point of reference, from 1965 to 1970 dietary intake of DDT was 0.0007 mg/kg body weight/day. Other investigations further disclose that except for unavoidable background levels in certain foods, the PCB contamination of food can be significantly reduced or eliminated through appropriate controls.

Man and the Ecosystem

In air and water away from immediate sources of waste discharge, levels of PCBs are low -- a few micrograms per cubic meter (parts per trillion; ppt) in air and less than a part per billion (ppb) in fresh water; soil or bottom sediments contain a few parts per billion, up to several hundred parts per million (ppm) near some industrial outfalls; from tenths of a ppm to tens of ppm in fish and up to hundreds of ppm in some fish and birds near the top of the food chain. To illustrate these relationships, 1/8 of an inch is about

one trillionth of the distance to the moon; and a part per million is about 5 steps on a walk from Washington to San Francisco.

Man, who is at the top of a food chain, may also have PCB residues in his body fat. Analyses of tissue residues from 688 persons from three States showed two-thirds to have detectable residues, but only one-third contained residues of 1 part per million or more.

PCBs have been shown to accumulate in fish and aquatic invertebrates to levels of 75,000 times that present in the water, and to be accumulated from concentrations as low as 0.06 parts per billion (the lowest concentration for which experimental data are available). Thus, to keep levels in fish as low as possible, and in any case from reaching the 5 parts per million established by FDA as an interim action level for safety as food, concentrations in water should be less than 0.07 part per billion, or to allow some safety factor, 0.01 ppb. This level in water should be sufficiently low that fish and shellfish are not themselves adversely affected.

Existing data suggest that the principal route of PCBs through the environment is from waste streams into receiving waters, downstream movement in the waterways in the water and on sediments, accumulation from the water by aquatic organisms, and transfer to birds and mammals (including man) through residues in fish that are eaten.

Another route to man is through migration of residues to foods from PCB containing packaging materials. A third route to man may have been absorption through the skin from handling carbonless carbon paper. These exposures are being rapidly diminished since PCBs are no longer used in carbonless carbon paper. Presumably most of the PCB residues in paper made from waste paper also came from used carbonless carbon paper, which is no longer used in making food packaging material.

V.A. BIOLOGICAL EFFECTS ON MAN (METABOLISM, TOXICOLOGY, AND RESULTS OF HUMAN EXPOSURES)

Human beings occasionally have been exposed to high levels of PCBs. Some exposure has been the result of occupational experience or of accidental concentrations in food as in the accidental contamination of rice oil in Japan ("Yusho" episode). As far as can be determined, the number of exposed persons in these cases has been limited. Another source of contamination and exposure (although at a lower level) has been fish containing PCBs.

Samples of human fat have been examined to a limited extent for the presence of PCBs. As a result of this limited sampling, it has been concluded that some persons carry a body burden of PCB in their fat tissue. In contrast to the ubiquity and levels of DDT and its metabolite, DDE, in humans in this country, the current levels of PCBs do not appear to be as uniform in distribution. At the levels in which they are found, PCBs do not appear to present an imminent hazard.

The acute toxicity of commercial PCBs in experimental animals appears to be low. In the case of the human exposure with the Yusho episode, the average dose to that exposed population was calculated as 2 gm. From this incident, it was estimated that the minimum dose necessary to produce positive clinical effects was 0.5 gm.

With a sufficiently high dose it is possible to distinguish a number of toxic actions of PCBs and their contaminants in mammals. Alterations in the functioning of the liver have been observed in a number of species, and these are attributed to PCBs. It is likely that other conditions, such as chloracne (severe skin eruptions), liver damage, and hydropericardium (accumulation of fluid in the sac which surrounds the heart) may be caused by a contaminant, chlorinated dibenzofuran.

The limited mammalian chronic studies of the Monsanto Company indicate no evidence for carcinogenicity. The possibilities of embryotoxicity and mutagenicity, however, are poorly studied and, hence, are ill-defined.

Because of the possibility of human exposure to PCBs, the task force recommends the following additional studies:

1. Toxicological evaluation of a select number of representative, purified PCB isomers as well as purified trace contaminants such as the chlorinated dibenzofurans.

2. Definitive mammalian elaboration of the kinetics, absorption, distribution, metabolism, and excretion of the technical PCBs as well as a number of key isomers and the chlorinated dibenzofurans.

3. Elaboration of the subcellular and intracellular actions of the technical PCBs as well as a number of representative isomers and chlorinated dibenzofurans.

4. More definitive epidemiological studies of the PCBs with both more representative population sampling and standardization on the basis of lipid content of the tissues.

V.B. BIOLOGICAL EFFECTS ON ANIMALS OTHER THAN MAN

The significance of PCBs to wild animals depends primarily upon the sublethal physiological effects of these substances rather than upon their lethal toxicity. They have accumulated in all portions of the natural environmental complex in a manner predictable from their high solubility in fat and their resistance to degradation.

PCBs can be lethally toxic to some fish and aquatic invertebrates when concentrations in the water are parts per billion or less. They are metabolized and excreted very slowly by these organisms.

They are only moderately toxic to birds and mammals; lethal levels are similar to those of DDE. PCBs may have contributed to direct mortality of some adult birds in the field, but not to an extent to affect populations.

In sublethal exposure, PCBs are physiologically active and induce enzyme activity. Direct effects on reproduction have been shown for chickens, but not for ducks, quail, or doves. Some studies tentatively suggest the possibility of subtle behavioral effects and of interactions with disease organisms or other environmental chemicals.

Full evaluation of actual or potential effects in the environment is hampered by the complex nature of the mixtures that compose PCBs, and by the inclusion of contaminants in these mixtures. As experimental studies have been conducted with the unaltered products, as sold, the results may not properly reflect the effects of the components as they exist in the environment.

Although fully conclusive data are not available, the evidence for toxic and physiological effects indicates that the PCBs must be viewed as potential problems at present environmental levels.

FOOTNOTES

1. Nisbet, I.C.T., and A.F. Sarofim, "Rates and Routes of Transport of PCBs in the Environment". Paper delivered at International Scientific Meeting on PCBs sponsored by the National Institute of Environmental Health Sciences, and held at the Quail Roost Conference Center, Rougemont, North Carolina, December 20-21, 1971. (Environmental Health in Perspective (in press) 1972.)

2. Data supplied by the Monsanto Company.